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ABSTRACT

THIS IS ONE OF A SERIES OF UNITS INTENDED FOR BOTH PRESERVICE AND INSERVICE ELEMENTARY SCHOOL TEACHERS TO SATISFY A NEED FOR MATERIALS ON "NEW MATHEMATICS" PROGRAMS WHICH (1) ARE READABLE WITH MINIMAL INSTRUCTION, (2) SHOW THE PEDAGOGICAL OBJECTIVES AND USES OF SUCH MATHEMATICAL STRUCTURAL IDEAS AS THE FIELD AXIOMS, SETS, AND LOGIC, AND (3) RELATE MATHEMATICS TO THE "REAL WORLD," ITS APPLICATIONS, AND OTHER AREAS OF THE CURRICULUM. THIS UNIT CONTAINS A COLLECTION OF REFERENCES ON THE APPLICATION OF MATHEMATICS TO OTHER SUBJECT AREAS IN THE ELEMENTARY SCHOOL CURRICULUM. THE MAJOR MATHEMATICAL CATEGORIES INCLUDED ARE APPLICATIONS INVOLVING (1) NUMBER AND OPERATION, (2) MEASUREMENT AND APPROXIMATION, (3) ORGANIZATION AND PRESENTATION OF DATA, (4) ALGEBRA, (5) RATIO, PROPORTION, OR COMPARISON, (6) GEOMETRY, (7) PROBABILITY AND STATISTICS, (8) PROOF AND DEDUCTIVE INFERENCE, AND (9) SETS. (RP)

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# USES OF MATHEMATICS IN OTHER SUBJECT AREAS

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OFFICE OF EDUCATION

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Every teacher of mathematics has been confronted with the question "What good is this stuff, anyway?" Sometimes one is able to show some applications that are meaningful to the students; sometimes one merely sketches areas where the material could be useful in later life or later in school; sometimes one must answer "This is necessary to develop more mathematics, which will be of considerable use to you"; sometimes, if one is honest, he will be forced to answer "I really don't know".

Elementary school students live in a world full of interesting things. They want their learning to be meaningful - that is, to be useful in dealing with the world as they see it. Elementary teachers have an excellent opportunity to make the learning activities of their students more meaningful by relating subject areas to one another. This means, of course, that the teacher should be alert to places where various subjects can be interrelated.

This unit is a collection of applications of mathematics to other subject areas in the elementary school curriculum. Many of the applications given here have been drawn from existing texts, either commercial or experimental. Other ideas have been suggested by creative elementary teachers. Still others have been suggested by college professors or specialists in particular subject areas. The sources are identified by a key which refers to the appropriate reference in the bibliography at the end of the unit. Applications which are not keyed are those which are found in many sources.

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This collection of applications is by no means exhaustive. A creative teacher can easily think of many more places where mathematics is, or can be, used in the elementary school. This unit is, however, a source which can be used by teachers, and which can serve as the starting point for a much larger collection of applications.

The unit is organized into major mathematical categories, which are often broken down into subcategories. Within each of these categories, the applications are grouped by subject area.

Among the applications given, those in the field of science predominate. There are two main reasons for this. First, science is the subject which has traditionally made the greatest use of mathematics. Second, science happens to be the author's primary area of competence outside the field of mathematics.

Although grade level designations are included in many cases, these should not be considered definitive. It has been demonstrated in research and in experimental projects that many ideas can be introduced much earlier than was previously believed possible. An application should not be considered to be fourth grade simply because it appears in a fourth grade text. It may be profitable to introduce that particular application earlier or later, or use it at several grade levels.

The author would like to acknowledge the help, suggestions, and advice of a number of people: our reader-critics, Mrs. Patricia Edmister and Mrs. Jennie Dubois, for an excellent list of applications in many different subject areas; Professor Waldo Tobler of the Geography Department of the University of Michigan, for a fascinating 40 minutes in which new worlds of mathematical application were opened up; Dr. Theral T. Herrick, Executive Director of the Michigan Council of Economic Education, for his

enthusiasm, suggestions, and generous loan of materials; Donald Beard, Assistant to the Director of the Institute for Economic Education, for a number of helpful suggestions; and the writers and advisors of the Elementary Materials Writing Project, for their helpful reactions to the author's ideas.

Explanation of the Key

The key consists of some letters, a parenthesis containing numerals, letters, or both, and a numeral following the parenthesis.

The first letters designate the subject area: Sc for science, SS for social studies, E for economics, P for personal interview. The last letter before the parenthesis identifies the particular text series, book, or person.

The parenthesis includes the particular book in a text series, by grade level or title, and whether the book is a pupil book (PB), teacher's guide (TG), or teacher's edition (TE).

The numeral at the end indicates the page or pages on which the application is located.

Examples:

(1) ScA(1-TG)--75 means the first series listed in the science section of the bibliography, Concepts in Science, the first grade teacher's guide, page 75.

(2) SSH(ITA-PB)--314 means Social Studies, entry H, The Basic Social Studies Program. "In the Americas", pupil book, page 314.

## I. Applications Involving Number and Operation

This heading includes the most basic applications--those involving information in quantitative form, or straightforward calculation. These are applications, although not high-level ones.

### A. Numerical Facts

These are a selection of the many facts given in numerical form in texts.

SCIENCE

Astronomy

1) A year is approximately 365¼ days long.

2) The moon orbits the earth in about 29½ days. ScD(3-TE)--152.

3) The sun is about 93,000,000 miles from the earth. ScC(2-TE)--124; ScA(2-TE)--64.

4) The day is 24 hours long. ScC(2-TE)--125.

5) Escape velocity (the speed necessary to escape permanently from the earth) is 25,000 miles per hour. ScK(1-TE)--31; ScC(3-TE)--192; ScA(5-TE)--128.

6) The average distance from the earth to the moon is 240,000 miles. ScC(3-TE)--192.

7) The duration of a total eclipse is 7½-8 minutes. ScJ(Five-TG)--76.

8) The time of orbit for an astronaut about the earth is 88 minutes, for the moon around the earth 28 days, for the earth around the sun 365 days, and for Halley's comet around the sun 76 years. ScA(4-TE)--267.

9) 59% of the moon's surface has been observed by astronomers. ScK(5-TE)--69.

10) The distance from the earth to different stars varies from 12 light-years to 1,600 million light-years. ScA(2-PB)--127.

11) The temperature of the sun is about 11,000° F. The temperature of the red star Antares is 5,500° F. The temperature of the blue-white star Deneb is about 22,000° F. ScA(6-PB)--372-374.

Botany

1) There are more than 1700 different plants generally known as cactus. ScK(4-TE)--98.

Chemistry

1) When iron rusts, about 1/5 of the air in the test tube is used up. ScA(4-TE)--T-86.

2) The total amount of sugars made on the earth by green plants in one year has been estimated at 400,000,000,000 tons. ScA(4-TE)--67,116.

3) In 10,000 molecules of air, there are 7,800 molecules of nitrogen, 2100 molecules of oxygen, 90 molecules of argon, 4 molecules of carbon dioxide, and 6 molecules of other gases. ScA(4-TE)--103.

4) A cubic yard of seawater contains, on the average, 730 oz. of salt (sodium chloride), 32 oz. of magnesium and magnesium compounds, 10 oz. of calcium and calcium compounds, 9.5 oz. of potassium and potassium compounds, 1.6 oz. of bromine, and 22 oz. of sulfur and sulfur compounds. ScA(6-PB)--321.

Geology

1) The earth is made up of three sections, the crust, the mantle, and the core. The crust is only a few miles thick, and the core is about 4000 miles in diameter. The mantle lies between the crust and the core. ScD(3-TE)--34-5

2) There are three main kinds of rocks (igneous, sedimentary, metamorphic) and two main types of coal (anthracite and bituminous). ScK(4-TE)--75.

3) The Paleozoic Era was more than 200,000,000 years ago. ScK(4-TE)--83.

4) The temperature at a depth of 1 mile within the earth is 3300° F. The temperature within the core is about 10,000° F. ScK(5-TE)--135.

Meteorology

1) The depth of the troposphere (the part of the air closest to the earth) is about 4-5 miles at the Poles and 7 miles at the equator; the average is about 7 miles. ScD(6-TE)--10

2) The percents of the four permanent gases in the atmosphere are, approximately, Nitrogen, 78%, Oxygen, 21%, Argon, 0.9%, Carbon Dioxide, 0.03%.

3) Jet streams are thousands of miles long, and up to 300 miles wide. The average speed in the center is 200 miles per hour, but it may range up to 400 miles per hour. The average speed at the edges is 30 miles per hour. A jet stream lasts about 40 days, and follows a regular cycle. ScD(6-TE)--60-1.

Physical Geography

1) A desert is defined to be a region which receives less than 10 inches of rainfall a year, on the average. ScD(6-TE)--60-1.

2) Each 15° on the globe makes a difference of one hour in time. ScC(1-TE)--288.

3) The axis of the earth is tilted at an angle of 23½°. ScK(2-TE)--14; ScK(5-TE)--87,90.

4) Half the earth is light and half the earth is dark at any given time. ScA(1-TE)--51.

5) The time for the earth to rotate once on its axis is 24 hours. ScA(2-TE)--128; ScA(5-PB)--112.

6) There are 15° between principal meridians. ScK(4-TE)--38.

7) The tide rises or falls about every six hours. ScK(4-TE)--133.

8) Water covers more than 75% of the earth. ScK(5-TE)--156.

9) The earth spins on its axis in 23 hours, 56 minutes, and 4.1 seconds. ScK(4-TE)--41.

Physics

1) Sound travels at approximately 1100 feet per second.

2) The frequency of ultrasonic vibrations is greater than 20,000 vibrations per second. ScD(5-TE)--220.

3) The temperature drops approximately 3°F. for every 1000 feet of elevation. ScD(6-TE)--12.

4) Water weighs about 62.4 pounds per cubic foot. The maximum density of water occurs at 39.2°F. ScK(2-TE)--95.

5) An increase of 36°F. increases the speed of sound by 40 feet per second. ScK(2-TE)--115.

6) It takes 75 dry cells to equal normal house voltage. ScC(3-TE)--174.

7) Two-thirds of the lift on an airplane is accounted for by the pressure above the wing being less than the pressure under the wing. ScJ(Five-TE)--91.

8) It takes approximately 2.6 seconds for a radio wave to go to the moon and return. ScA(5-PB)--295.

9) There are 6 simple machines: the wheel, the inclined plane, the pulley, the wedge, the screw, and the lever. ScK(4-TE)--168.

10) Molecules moving from one position to another account for about 60% of the energy generated when a gas is heated to a moderate temperature. The other 40% can be attributed to the rotational motion of the molecules. ScK(5-TE)--23.

11) Double-acting steam engines are most frequently built in sizes of less than 500 horsepower. ScK(5-TE)--46.

12) Diesel engines having from 100 to 5000 horsepower are used to generate electricity for hotels, factories, hospitals, campsites, and military bases. ScK(5-TE)--49.

13) One must be at least 56 feet from a wall to hear an echo. ScK(5-PB)--21.

Physiology

1) A child has about 3½-4 quarts of blood, while an adult has about 5-6 quarts.

2) The average body temperature for a human is 98.6°F. ScK(4-TE)--213-214.

3) The heart-beat rate for fourth graders is about 85-90 beats a minute. ScK(4-PB)--261.

4) If two sounds occur within one-tenth of a second of each other, they are heard as one sound. ScK(5-TE)--9.

Zoology

1) The number of chromosomes varies greatly for different creatures. There are 200 chromosomes in a crayfish cell, 48 in a potato cell, and 46 in a human cell. ScD(5-PB)--278.

2) It takes 21 days for chicks to hatch from eggs. ScA(1-TE)--146.

3) Many hens lay more than 100 eggs a year. ScA(2-TE)--103.

4) The body temperature of a bird is about 104°F. ScA(5-PB)--179.

5) There are more than 5000 species of animals on the American desert. ScK(4-TE)--100.

6) When a hamster hibernates, its body temperature is 50°F. For some hibernating animals, the body temperature may go as low as 45°F., with breathing occurring once in 5 minutes, and only 4-5 heart beats per minute. ScK(5-TE)--94.

SOCIAL STUDIES

1) One person out of 16 in the world today is an American. SSD(TE)--T-32.

2) The Senate has 100 members, two from each state. The House of Representatives has 435 members. SSD(TE)--T-57.

3) If the population of the United States continues to grow at its present rate, by 1970 it will be about 210 million. SSD(TE)--31.

4) The lines separating the Eastern and Western hemispheres are usually drawn at 20° W. longitude and 160° E. longitude. SSB(4-TE)--114.

5) In the United States Mint, 4,500,000 pennies are made each hour, out of 30,000 pounds of copper, tin, and zinc. Each press stamps 7200 pennies an hour. SSH(ITA-PB)--170-1.

ECONOMICS

1) Just to maintain full employment when we have it, the gross national product (GNP) in the United States must increase about 4% annually. EF--23.

2) There are four major classes of incomes. These are: (1) wages and salaries; (2) interest; (3) rent; (4) profits. ED--55.

B. Recording Experimental Results

Many experiments yield results in quantitive form. The recording of this numerical data is important and frequently provides the raw material for mathematical analysis. The reasoning process, which draws conclusions from the results of the experiment, is also mathematical in nature.

SCIENCE

Botany

1) The rate of growth of tomato plants may be compared when the amount of detergent to which they have been exposed is varied. ScE--48.

2) The energy released by plants as they grow can be measured by measuring the movement of a plastic cup as bean seeds or corn seeds sprout under it. ScD(5-PB)--100.

3) The growth of plants in sandy soil and topsoil may be recorded day by day, to provide a comparative growth record. ScC(2-TE)--194-5.

4) A record may be kept of the growth of roots, stems, and leaves of bean seeds put in a jar with blotting paper. ScC(2-TE)--199.

5) After plants have sprouted from seeds, the plants are separated into three groups. Some have one seed half removed, some have both seed halves removed, and some are left intact. A growth record, by group, is kept. ScC(4-TE)--43.

6) The water content of potatoes and apples may be found by heating them gently until they are largely dehydrated. ScC(4-TE)--174.

7) Plant 30 Lima bean seeds in a box. After they show above the soil, pull up a plant a day, and record the growth. ScK(2-PB)--57.

8) The growth rate of seeds may be determined by opening one every four days. ScI(2-PB)--105.

9) The age of a redwood tree may be determined by counting its rings. ScC(3-TE)--103.

10) The weight of apples may be determined before and after drying, to determine the moisture content. ScJ(5-TE)--141; ScA(4-TE)--T-50; ScA(4-PB)-87.

11) A study of the effect of water on plant growth may be carried out. Beans may be planted in two cups, and one given a spoonful of water a day, while the other is given only a drop. ScA(1-TE)--96-7.

12) Cans of beans could be examined to determine whether canners sort beans by size for different can sizes. ScH(VM)--22.

13) The variation in the number of raisins in raisin bread can be investigated. ScH(VM)--24-26.

14) The shape and size of mold plants may be determined. ScG(Two)--189-193.

15) The increase in size of seeds soaked in water may be measured. ScG(Two)--253-258.

16) The relation between temperature and growth of bread mold may be studied by using a range of temperatures, such as 4°C., 20°C., 40°C., 60°C. ScG(Six)--849-853.

17) A balance may be used to measure the evaporation of water from the leaves of a plant. A plant may be put in a pot wrapped in aluminum foil, with only the leaves exposed. The plant may then be balanced by a pot similarly wrapped, but containing only soil. The weight of moisture lost through evaporation may be checked at various times. ScC(4-TE)--179.

18) An experiment may be performed to determine the best planting depth for certain types of seeds, by planting seeds at various depths and treating them the same in other ways. ScF--171.

19) The effect of capillarity in plants may be investigated by letting a plant be "watered" with red ink and observing the rise of the ink after the plant has sat overnight. ScC(3-TE)--102.

Chemistry

1) Iron filings may be weighed, moistened, and set in the air. After the filings have rusted, they are weighed again. This will establish that the weight of iron rust is greater than the weight of the iron which rusted. ScD(5-PB)--25.

2) The amount of sugar that can be dissolved in a given amount of water can be determined. ScC(4-TE)--447.

3) The time needed for ink to mix with hot water and with cold water can be found by experiment. ScA(6-PB)--58.

4) A measured amount of solution may be allowed to evaporate, and the weight of the residue determined. ScH(RPM)--44-47.

5) A solution may be measured at different points in the container, to measure differences in the concentration of the solution. ScH(RPM)--54.

Geology

1) A rock may be approximately dated in the following way: If 500 years is required to form one inch of sedimentary rock, then 500,000 years would be required to form 1000 inches of this rock. ScA(5-PB)--315.

Meteorology

1) Inside and outside temperatures may be recorded for

a week, to get a temperature record over a period of time. ScC(2-TE)--42.

2) An experiment which simulates the effect of clouds on temperature can be carried out. Thermometers are placed in two jars, and the tops are covered with aluminum foil. A sheet of tissue paper is placed around one jar. The jars are then placed in bright sunlight, and temperature readings are taken. ScC(4-TE)--94.

3) A weather record, including temperature, may be kept for a month. As a comparison, another month record may be kept during a different season of the year. ScK(2-TE)--10.

4) A daily temperature record may be kept. ScK(2-PB)--25.

5) Weather balloons are used by scientists to measure the temperature of the upper air. ScK(2-PB)--122.

6) The cooling effect of a wind can be simulated. An electric fan can be used to supply the "wind", and its effect on the temperature of a can of hot water can be measured. ScJ(2-PB)--143.

7) Records may be kept, over a period of several months, of the temperatures of several cities. The effect of latitude, season, proximity to water, and other local conditions on temperature may be noted. ScK(5-TE)--99.

Physical Geography

1) The length and the location of the shadow from a stick may be recorded at various times of day. ScC(2-TE)--127; ScJ(2-PB)--44; ScK(4-TE)--39-40.

2) The amount of rainfall in a given amount of time may be measured on several different occasions. ScA(1-TE)--43.

3) The question "Do we have the same amount of daylight in every day?" could be investigated. ScB--50.

Physics

1) An experiment to determine the relative distance sound may be heard through different media may be carried out. An alarm clock is moved away from a student until he can no longer hear the clock ticking. This distance is measured and recorded. This has been performed with the student listening through the air as usual. Then it is repeated with the clock moved along a chalk rail against which the student has placed his ear. ScD(1-TE)--15.

2) A thermometer is used to check the rapidity with which the air heats up in a terrarium. Thermometer readings are taken at regular intervals. ScD(2-TE)--59.

3) Thermometers are placed in (a) a shady place, (b) a sunny place, covered with a white cloth, (c) a sunny place, covered with a black cloth. Readings are taken after a suitable time interval, and comparisons are made. ScD(2-TE)--7.

4) The relative holding powers of different types of soil are compared. A given amount of water is poured on samples of clay soil, sandy soil, and loam. The amount of water passing through each is measured. (The soil samples must be the same thickness for the experiment to be meaningful). ScD(2-TE)--49.

5) Absorption and reflection of radiant energy may be measured by wrapping a glass of water in black paper and another in white paper, getting the glasses at the same initial temperature, setting them in the sun for half an hour, and then taking temperature readings. ScD(4-TE)--153.

6) Thermometer readings can be taken to determine which gets hotter on a bright summer day--a light-grey sidewalk or a black asphalt pavement. ScD(4-TE)--211.

7) The relative strength of electromagnets may be compared. ScE--59.

8) The strengths of electric currents through various solutions may be compared. ScE--63.

9) An ice cube may be inserted in some water to chill it, and then removed. The temperature of the water may be recorded at intervals. A similar experiment would be to add ice cubes to water, and record the temperature at intervals until after the ice cubes have melted and the temperature has stabilized. ScE--73-4.

10) A can of water may be surrounded by an ice-salt mixture, and readings taken until after the ice cubes have melted. ScE--91.

11) The temperature rise resulting from shaking water in a vacuum bottle is a measure of the conversion of mechanical energy into heat energy. ScD(5-PB)--178.

12) A dry cell and nail may be used to raise water temperature, and the temperature recorded at intervals. ScD(5-PB)--199.

13) An experiment to investigate the effect of the evaporation of a drop of water on the reading of a thermometer may be

carried out. One drop should be picked up from a bottle of water, on the bulb of a thermometer. The drop can be held inside the bottle, but about 1 inch out of the water. A second drop should be picked up similarly, and held completely out of the bottle. ScD(6-PB)--38.

14) The effect of color on heating may be measured by using a lamp, covering one thermometer with white and a second thermometer with black, and taking readings every 30 seconds. The experiment may be repeated, except red and black covers could be used. ScD(6-PB)--52.

15) The rate of heating of soil and water are compared. The heating agent is a desk lamp. Thermometer readings are taken every 30 seconds. ScD(6-PB)--53.

16) The freezing point of water can be established. ScC(2-TE)--45.

17) The result of putting a thermometer into warm water can be recorded. ScC(2-TE)--45.

18) A record may be kept of the readings of thermometers located in different places in a room. ScC(2-TE)--46.

19) The water temperature in a fish tank may be recorded before and after ice cubes are put in the water. ScC(2-TE)--103.

20) The rate of evaporation of a cupful of water placed in the sunlight may be compared with the rate of evaporation of a cupful of water kept in the dark. ScC(2-TE)--116.

21) A comparison may be made between the temperature of water kept in the shade with water kept in the sunlight. ScC(4-TE)--90.

22) The rates of warming of water and soil can be compared. Readings may be taken at the surface of the ground and at a depth of one foot. The procedure may then be repeated using a vessel of water, rather than soil. ScC(4-TE)--96.

23) Some soil and some water at the same temperature may be placed in a refrigerator for 15 minutes. After this time, their temperatures are taken to determine the cooling rates of water and soil. ScC(4-TE)--97.

24) The degree to which sunlight warms a piece of paper in a 10-minute interval may be determined. ScC(4-TE)--133.

25) The effect of electric light on the temperature of white and black paper may be investigated. ScC(4-TE)--138.

26) The weight of water may be established experimentally. ScC(4-TE)--172.

27) The force necessary to turn a book if marbles are used as ball bearings may be investigated. ScC(4-TE)--201.

28) The propellor thrust of a toy motorboat may be measured. ScC(4-TE)--228.

29) The effectiveness of one's breath in moving a toy boat with and without a sail may be measured. ScC(4-TE)--245.

30) The work done by a paper water wheel in lifting an empty cup and a full cup may be determined. ScC(4--TE)--248.

31) The effect of sunlight on heating a thermometer through a thick blanket and through a thin one can be compared. ScC(4-TE)--287.

32) The amount of moisture in snow may be determined by collecting a certain amount of snow, melting it, and measuring the amount of water obtained. ScC(4-TE)--410.

33) Aquarium temperature may be compared with room temperature and with outside temperature. ScK(2-TE)--48.

34) A temperature record of a water-crushed ice mixture could be kept while the water is being frozen. ScK(2-TE)--94.

35) The temperature of cold tap water may be compared with the temperature when the water has sat in bright sunlight for 2-3 hours. ScK(2-TE)--109.

36) The moisture content of the soil may be measured by weighing the soil, heating it for a time to drive out the moisture, and reweighing. ScK(3-TE)--5,6; ScK(3-PB)--12,13,16,17.

37) The force needed to lift a book using a pulley may be determined. Then the pulley can be oiled until consistent readings are obtained, to get a measure of how much friction there had been. ScK(3-TE)--77-8; ScK(3-PB)--130. It may further be shown that friction still remains after oiling. ScK(3-PB)--132.

38) The mechanical advantage may be calculated for various devices, such as single-strand pulleys, double-strand pulleys, single blocks and tackles, and double blocks and tackles. ScK(3-TE)--80-1.

39) The weight of air may be measured by weighing a basketball on a sensitive balance before and after it is inflated. ScK(3-PB)--25.

40) The force needed to lift a book when two pulleys are used may be determined. ScK(3-PB)--134.

41) The force necessary to raise an object using a movable pulley may be determined by experiment. ScK(3-PB)--133.

42) The amount moved by a box with wheels and a box of the same size without wheels, when both are given the same initial push, may be determined. ScJ(2-PB)--172.

43) The amount of water evaporating from a cloth in a given time may be measured. ScJ(3-TE)--30-1.

44) The amount of water needed to keep the water line of an aquarium constant may be determined. ScJ(3-TE)--31.

45) A study can be made of the number of seconds candles burn in containers of various sizes. ScJ(3-TE)--49; ScJ(3-PB)--69-71.

46) A comparison could be made of the amount of mud settling from 2 trays, one containing just soil, and the other containing soil covered with leaves and grass. ScJ(3-PB)--143.

47) The buoyancy of water may be determined. ScF--50.

48) The distance a ticking clock can be heard when listening with a paper horn or with the unaided ear may be determined. ScC(3-TE)--10.

49) The difference in temperature between the surface of a flowerpot and 4" below the surface of the soil in the pot can be determined. Two thermometers should be used, and the readings collected in sunshine. ScC(3-TE)--26.

50) The insulating effect of fur or wool may be studied, by wrapping the material around jars of hot water or cold water and recording the temperature changes over a period of time. ScC(3-TE)--138.

51) The insulating effect of tightly-wrapped paper may be compared with that of loosely-wrapped paper, on jars of hot water. Temperatures can be taken at 10-minute intervals. ScC(3-TE)--139.

52) Ice cubes may be placed inside an ordinary paper bag and an ice-cream bag, and the temperatures recorded over a period of time. ScC(3-TE)--143.

53) A book may be suspended from a ruler at various distances from the end of the table and the amount of torque determined. ScC(3-TE)--156-161.

54) A wedge may be pushed through some soil, after which the width of the wedge may be compared to the distance the sand is pushed to the side. ScC(3-TE)--171.

55) The evaporation rate of water in a covered glass may be compared with the evaporation rate of water in an open glass. ScC(3-TE)--253.

56) The number of nails picked up by an electromagnet with 20 turns of wire may be compared with the number picked up by an electromagnet with 40 turns of wire. ScJ(5-TE)--186.

57) The center of weight of an object may be determined by hanging weights from the object by strings, one at a time, and marking the line from the point of suspension to the weight. The point where these lines intersect is the center of weight. ScJ(5-TE)--58-63.

58) A comparison may be made of the times of fall from a given height of different sizes of parachutes, and objects of different weights. ScJ(5-TE)--221.

59) The temperature reading on a chunk of ice and in a sunlit window may be taken at 9 A.M. and at 12 noon. ScA(1-TE)--33.

60) The time required for ice to melt in sunlight and in shade may be determined. ScA(1-TE)--33.

61) The time necessary to burn ½" of paraffin on a candle may be determined. ScA(4-PB)--45.

62) Temperatures may be taken in different locations in a refrigerator. ScA(4-PB)--45.

63) Compare the force necessary to lift an object with a spring balance and the force necessary to pull the same object up an inclined plane. ScA(6-PB)--155.

64) The effects of fixed pulley, movable pulley, and block and tackle on effort can be investigated. ScA(6-PB)--167-9.

65) The temperature of air, soil, and tap water may be compared. ScK(4-PB)--81.

66) The temperature of snow, melted snow, and ice may be compared. ScK(4-PB)--81.

67) The temperature of an ice-salt mixture may be determined. ScK(4-PB)--83.

68) The increase in velocity of a falling object may be investigated. ScK(5-TE)--5.

69) A weight is suspended by a string, and also has a string attached below. An experiment is conducted to determine where the strings break under (a) a slow, steady pull; (b) a quick, snapping pull. ScK(5-TE)--8.

70) The heat loss of hot water in containers of various types may be investigated. ScK(5-TE)--33.

71) An experiment or series of experiments may be conducted to learn what happens when equal amounts of water at different temperatures are mixed. ScK(5-TE)--34.

72) To investigate whether slanted rays from the sun give off more or less heat than less slanted rays, prop thermometers up at different angles against stacks of books, and place in the sun. Check the thermometer readings after a few minutes. ScK(5-TE)--99.

73) An experiment concerned with the radiation and absorption of heat can be carried out easily. Paint one can black on the outside, polish the outside of a second can, place thermometers with the bulbs inside the cans, and place the cans in direct sunlight. ScK(5-PB)--53.

74) Several differently-shaped containers may be filled to the same level to learn which contains the most liquid. ScH(VM)--52-3.

75) The distance traveled in n revolutions of a disk by objects at different places on the disk may be determined. ScG(Three)--437-441.

76) The drying rates of different fabrics may be determined. ScG(Four)--509-514.

77) The breaking strength of a string may be determined. ScG(Five)--731-736.

78) A fluid may be heated over a period of time, and the temperature may be recorded against the time heating has gone on. ScG(Six)--905-911.

79) The effect of a certain amount of heat on different volumes of water may be investigated by performing the same sort of experiment as (78) for several different volumes. ScG(Six)--905-911.

80) The relation of heat energy to work may be investigated by such experiments as: Hammering a piece of lead; Pumping a closed-off tire pump; Using a fire-by-friction kit; Pushing a can of water back and forth in a friction trough. ScG(Six)--913-916.

81) The weight of water in milk may be determined by evaporating the milk gently with the aid of a hot plate. ScD(4-TE)--55.

82) Electric current may be measured by using zinc and copper strips and hooking them to a sensitive ammeter. Examples of things which can be checked for current are a lemon and the surface of the human tongue. ScD(4-TE)--117.

83) An interesting experiment is the measurement of the rate of heat conduction of various materials. ScF--106.

84) An experiment investigating the law of the lever may be carried out using a ruler as the lever, a pencil as the fulcrum, and paper clips as weights. The experiment may be carried out in the following way: Put one paper clip at one end of the ruler, and find the place where 2 will balance it; Put 2 at one end, and balance them with 2, with 3, and with 4. ScC(3-TE)--170.

85) The temperature changes in air and water can be measured when two jars, one containing air, the other water are put in sunlight for three minutes. ScA(5-PB)--324-5.

86) The effect of heat on the inflation of a balloon may be studied by attaching a pointer to a sugar lump, putting a balloon (partially inflated) in a beaker above water, heating with a hot plate, and reading the movement of the pointer on a properly-mounted yardstick. ScA(6-PB)--196.

87) The force of a lever may be investigated by lifting an object with a spring balance, then lifting the same object with a rod used as a lever, when a spring balance measures the force exerted on the object. The experiment may be varied by the use of different fulcrums. ScA(6-PB)--157.

88) An experiment may be set up to study the difference between heat and temperature. An inch of near-boiling water may be poured over four ice cubes, while at the same time a full flask of cold water is poured over four other ice cubes. Then the cubes are watched to see which melt faster. AcA(6-PB)--375.

89) The specific heat of iron may be determined experimentally. ScK(5-PB)--35.

Physiology

1) The rate of breathing may be measured while one is sitting quietly and again after he has run in place for a minute. ScD(4-TE)--219. The pulse rate may be measured in the same way. ScD(4-TE)--221; ScK(3-PB)--151.

2) The clotting time of the blood can be determined. ScD(4-TE)--223.

3) The temperature in the crook of one's elbow may be compared with air temperature. ScC(4-TE)--201.

4) One may time how long he can hold his breath. ScK(3-PB)--147.

5) The number of breaths in one minute may be counted after: sitting; running; resting. ScJ(2-PB)--124.

6) The number of heartbeats in one minute may be counted after: sitting; running; resting. ScJ(2-PB)--127.

7) The height and weight of students may be recorded. ScA(2-PB)--121.

8) Each pupil can check his breathing rate for one minute. ScA(5-PB)--194.

Zoology

1) The breathing rate of frogs and other animals may be determined. ScK(3-PB)--151.

2) The length and height of a grasshopper jump can be determined. ScJ(2-PB)--7.

3) A fish's rate of respiration may be established by counting the movements of the open gill covers. The suggestion is to try water of different temperatures, in the range 30°F to 90°F. ScA(2-TE)--109.

ECONOMICS

1) The effect of inflation can be illustrated by having students lend packages of 100 sheets of paper and let the return be packages of 50 sheets of paper. EF--13.

2) The operation of lemonade stands can be used to dramatize price competition and non-price competition. EA(2)--10.

C. Calculations

In many texts, exercises are given to provide numerical practice or to fix an idea by providing examples. In this section, we have not reproduced the exercises, but have given sources where they are found. We have also described situations where simple numerical work, such as counting, takes place.

SCIENCE

Astronomy

1) The number of miles in a light-year is calculated. ScD(5-PB)--157.

2) Some numerical problems are given, involving the time for light to travel in space. ScA(6-PB)--386.

Botany

1) Counting leaves, including counting by 2's, 3's, and 5's. ScC(2-TE)--16.

2) Experiments where the number of peas in a pod are counted, and the relation of the number of peas to the size of the pod are investigated. ScH(VM)--14.

Chemistry

1) Calculating the time it takes for $CO_2$ to leave a jar, after the $CO_2$ has been produced by the reaction of baking soda and vinegar. ScK(3-PB)--82.

2) Calculating the number of protons in different elements. ScD(6-PB)--188.

3) The copper atom has 29 protons and 34 neutrons. What is its atomic number? ScK(5-TE)--201.

4) Exercises concerned with preparing solutions in different concentration. ScH(S)--35-8.

Physical Geography

1) 360° ÷ 24 hours = 15°/hour. Therefore, the earth rotates 15° per hour. ScC(2-TE)--332.

2) Calculation of the depth of the ocean from sonar readings. ScK(4-TE)--4.

Physics

1) The number of magnets appearing in a picture are counted. ScD(2-TE)--89.

2) Calculation of the work done when 4000 lb. is lifted 15 feet. ScD(3-TE)--82.

3) Calculating the speed, in feet per second and in miles per hour, of a "Mach 2" jet (a jet flying at twice the speed of sound). ScD(3-TE)--180.

4) The total air pressure on a desk top is calculated. ScD(4-TE)--41.

5) The amount of water in a 100-lb. person, if he is 2/3 water, is computed. ScD(4-TE)--53.

6) The amount of water used in producing a hamburger is discussed. ScD(4-TE)--64.

7) The time it takes light to travel from the earth to the sun is calculated. ScD(4-TE)--169.

8) The total air pressure on a sheet of notebook paper is calculated. ScD(4-TE)--211. The total air pressure on different-sized surfaces is computed. ScE--25; ScD(6--PB)--13.

9) Some exercises are included in which one figures gallons and pounds of rainfall. ScE--101-2.

10) Exercises are given where work is calculated. ScD(5-PB)--173.

11) An experiment involving lifting a weight by means of an inclined plane is carried out, and the energy waste is calculated. ScD(5-PB)--192.

12) The mass changed to energy through fusion is calculated. ScD(6-PB)--210, 212.

13) An exercise is given where one calculates the resistance in an electric circuit with a current of 10 amperes, and an electromotive force of 110 volts. ScD(6-PB)--281. Further exercises involving resistance are given. ScD(6-PB)--286.

14) Total pressure (the sum of water pressure and air pressure) per square inch and per square foot is computed for objects at various depths. ScD(6-PB)--305.

15) Exercises relating to the thermometer are included. ScC(4-TE)--85.

16) A height of 6 miles is computed in feet. ScD(4-TE)--271.

17) An exercise dealing with the tidal day. ScC(4-TE)--299.

18) Calculating work in foot-pounds. ScK(2-TE)--125.

19) Calculating the force needed to lift a book with a pulley. ScK(3-PB)--128.

20) An experiment involving the law of the lever as applied to a seesaw. ScC(3-TE)--171.

21) Exercises involving pulleys. ScA(5-PB)--170-1.

22) Exercises involving gear ratios. ScA(5-PB)--176.

23) Exercises involving work. ScA(5-PB)--186-8.

24) Exercises dealing with gravitational force, escape velocity, area, and work. ScA(5-PB)--228.

25) Exercises concerning time. ScK(4-TE)--52-3.

Physiology

1) To find the pulse rate per minute, find the number of pulses in 30 seconds, and double the result. ScD(2-TE)--107.

2) The number of times one's heart beats in a day or a week is computed. ScD(4-TE)--242.

3) Counting the number of times one inhales in a minute. ScK(3-PB)--145. Counting the number of times one inhales in a minute after running. ScK(3-PB)--146.

4) Counting heart beats for one minute. ScK(3-PB)--146.

Zoology

1) An exercise to calculate the number of bacteria produced in 12 hours if all survive and if the fission rate is 20 minutes. ScD(6-PB)--99.

2) Some pages give pictures of puppies or kittens, and ask pupils to count the number in the pictures. ScA(1-PB)--86-7.

3) In an aquarium, a gallon of water is needed for every inch of fish length. Several exercises are based on this. ScA(1-PB)--107.

4) Addition exercises are used to compare the weight of a Great Dane and a dachsund (for example, 6 dachsunds at 20 lb. weigh the same as one Great Dane at 120 lb.). ScA(1-PB)--113.

Miscellaneous

1) Counting the number of pieces of wood and the number of nails necessary to build some flooring. ScC(2-TE)--65.

2) Numerical exercises involving the number of trucks, the bricks in part of a brick sidewalk, the amount of cement, sand, and gravel used to make a concrete stairway. ScC(2-TE)--90.

3) A magnetic fish game is suggested. Three fish are caught by each child, the numbers on the fish are added, and the high total wins. ScC(2-TE)--160; ScA(1-PB)--26.

4) Exercises involving the differences in cost of shipping a 100-lb. crane from New York to San Francisco by truck, by train, and by airplane. ScC(4-TE)--268.

5) The number of quart milk cartons a dairy cow could fill in a day is discussed. ScA(2-PB)--101.

6) Counting backwards for a missile blast-off is mentioned. ScA(5-PB)--106.

SOCIAL STUDIES

1) Stories involving spending money. SSA(2-PB)--136-7.

2) Prices at a lunch counter discussed. SSA(2-PB)--154.

3) Various historical systems of numeration could be discussed in connection with the study of history.

ECONOMICS

1) Taking a lunch count.

2) Collecting money for various things.

3) Figuring income tax.

4) Different monetary units and rates of exchange.

MUSIC

1) The relationship between length of strings and octaves.

2) Numbers in key signatures.

3) The 8-note scale.

DRAMA

1) Figuring dimensions of scenery, the amount of things needed, etc., involve calculation.

READING

1) Roman numerals are sometimes used.

2) Calculating reading speeds involves counting and division.

PHYSICAL EDUCATION

1) Scoring of games, including point scores for activities such as tumbling, involves counting and calculation.

II. <u>Applications Involving Measurement and Approximation</u>

Under this heading, we have grouped those applications which especially emphasize the measurement process. This includes the use of special units of measure, of measuring devices of various

sorts, and of scales for ranking objects.

A. Units of Measure

These are units of some significance which are introduced in one or another of the sources.

SCIENCE

Astronomy

1) Light-year. The distance that light will travel in a vacuum in one year. (Light travels at about 186,000 miles a second). ScD(5-PB)--157; ScK(1-TE)--32.

2) Parsec. The distance at which the parallax of an object is slightly more than three light-years. ScD(5-PB)--157.

3) Astronomical unit (a.u.). The mean distance between the earth and the sun. Approximately 93,000,000 miles. ScK(5-TE)--76-7.

Physical Geography

1) Tidal day. The difference, in time, between two successive high tides. About 24 hours, 50 minutes. ScC(4-TE)--297.

Physics

1) Foot-candle. The amount of illumination shed by a standard candle (7/8 inch in diameter) at a distance of one foot from the candle flame. ScD(2-TE)--20.

2) Foot-pound. The amount of work done in lifting an object weighing one pound a vertical distance of one foot.

3) g. A force equal to the pull of the earth's gravity on an object located at the surface of the earth. In pulling out of a dive, airplane passengers may be subjected to a force of several g's. ScD(5-PB)--164.

4) Calorie. The amount of energy necessary to raise the temperature of one kilogram of water from 4°C. to 5°C. ScD(5-PB)--176; ScK(5-TE)--18-19; ScK(5-TE)--181.

5) calorie. 1000 calories = one Calorie. The Calorie is the commonly used measure of the energy content of food. ScD(5-PB)--176; ScK(5-TE)--181.

6) Mach number. A "Mach 1" airplane can fly at the speed of sound, a "Mach 2" airplane can fly at twice the speed of sound, etc. ScD(5-PB)--206-7; ScK(3-TE)--14.

7) Specific gravity. The ratio of the weight of an object to the weight of an equal volume of water. ScJ(Five--TE)--30-32.

8) Degree. The measure of an angle with its vertex at the center of a circle whose sides subtend 1/360 of the circumference. ScA(1-PB)--34.

9) Light-minute. The distance light travels in a vacuum in one minute. ScA(5-PB)--293-297.

10) Volt. An electromotive force of one volt will send a current of one ampere through a resistance of one ohm. ScK(4-TE)--156.

11) Ampere. A measure of electric current flow. The amount of electric current that will deposit silver at the rate of 0.001118 grams per second from a solution of silver nitrate in water. ScK(4-TE)--156.

12) Ohm. A measure of resistance to the flow of electric current. See Volt and Ampere. ScK(4-TE)--156.

13) Watt. A unit of power. In electricity, a watt is equal to the flow of one ampere at a pressure of one volt. That is, watts = volts X amperes. ScK(4-TE)--156.

14) Kilowatt. One kilowatt = 1000 watts. ScK(4-TE)--156.

15) B.T.U. Short for British Thermal Unit. The amount of heat necessary to raise the temperature of one pound of water one degree Fahrenheit. ScK(5-TE)--18-19.

16) Gram. The basic unit of mass in the centimeter-gram-second (cgs) system of measure. ScK(5-TE)--18-19.

17) Horsepower. A unit of power. 1 horsepower = 550 ft.-lb./sec.

18) Meter. A unit of length. One meter = 39.37 inches. ScG(Two)--177-80.

19) Decimeter. A unit of length. One meter = 10 decimeters. ScG(Two)--177-80.

20) Centimeter. A unit of length. One meter = 100 centimeters. ScG(Two)--177-80.

B. <u>The Use of Measuring Devices and Scales</u>

Much work involves the use of special types of measuring devices.

In other situations, special scales are devised for rating items.

Both of these applications are grouped together here.

# SCIENCE

## Astronomy

1) The scale of star magnitudes is an interesting example of the technique of scaling. A star of a particular magnitude is 2½ times brighter than a star of the next lower magnitude. The lower the number, the brighter the star. ScK(5-TE)--71; ScK(5-PB)--98.

## Chemistry

1) A study of the heat involved in a chemical change may be made by dissolving a given amount of detergent in a known amount of water, and measuring the rise in temperature of the liquid. ScD(5-PB)--23.

## Geology

1) Moh's scale of mineral hardness is used to rank mineral objects. The scale is a 10-point scale, based on what sort of mineral or object will scratch the mineral in question.

## Meteorology

1) A rain gauge may be constructed and used.

2) A simple barometer may be constructed. ScD(4-TE)--194.

3) A homemade anemometer may be constructed and used to measure wind speed. ScD(4-TE)--196; ScF--38-9; ScK(4-PB)--34-5.

4) Relative humidity may be measured, using wet-bulb and dry-bulb thermometers. ScF--108.

5) A hygrometer may be made by students to measure relative humidity. ScF--110.

6) The Temperature-Humidity Index is used to give a measure of how comfortable people are. For this reason, it was formerly called the Discomfort Index. ScD(6-PB)--91.

## Physical Geography

1) A sundial may be made and used. ScF--187; ScK(4-PB)--81.

2) A simple circular slide rule may be designed for telling time around the world. ScF--215.

3) Depth finders work through the use of sound waves, measuring the time intervals the sounds take to return to the source after bouncing off the bottom. ScC(3-TE)--18; ScK(4-TE)--4.

Physics

1) Comparison of the Fahrenheit and Celsius (Centigrade) temperature scales may be made. The Fahrenheit scale has 32° as the freezing point of water and 212° as the boiling point of water, hence it has 180 degrees in this interval. The Celsius scale sets the freezing point of water at 0° and the boiling point of water at 100°, hence this interval has 100 degrees. Thus the Fahrenheit degree is smaller, and above -40° (the point at which both thermometers read the same), the Fahrenheit thermometer will give a higher reading.

2) A bottle of colored liquid, with a glass tube, can be used as a thermometer. This would require calibration, using fixed physical constants, such as the freezing and boiling points of water, as reference points. ScD(4-TE)--145.

3) The relationship between heat and the expansion of iron may be studied by heating an iron wire with a candle flame, and measuring the amount of sag. ScD(5-PB)--33.

4) A cardboard thermometer can be made and used by students as they work on addition and substraction exercises. ScC(2-TE)--46.

5) Friction may be investigated using a spring balance. ScF--94.

6) The use of an air thermometer is discussed. ScF--196.

7) A tree may be measured by sighting with a stick and a 45° - angle line. ScF--198.

8) Objects may be weighed by balancing them by objects of known weight. ScJ(Five--PB)--52-3.

9) A spring balance may be used to find weights of objects. ScA(1-TE)--23.

10) Liquids may be ordered in viscosity by observing the rate of flow from a spoon. ScH(MO-PB)--45.

11) Liquids may be ordered in viscosity by the time it takes a standard object to fall a certain distance in the liquid. ScG(Five)--717-721.

12) Some possible classroom activities are: Measuring the length of pieces of licorice by using children's middle fingers or by using popsicle sticks; measuring the length of a ring which has a small cut; measuring the distance around concentric circles using as unit the length of one child's foot. ScH(VM)--35-39.

13) Identical cylindrical containers holding a liquid may be ordered by volume of the contents by simply ordering by the heights of the liquid. ScH(VM)--50-1.

14) Devices for measuring time include the metronome, the pendulum, the water clock, the sand glass timer, and a burning candle. ScG(Two)--273-278.

15) BB's may be used as standard weights, to balance objects such as screws. ScG(Five)--681-688.

ECONOMICS

1) A study of truth in packaging could involve a great deal of measurement. PE.

HISTORY

1) Different cultures use different calendars. Also, at different points in western history, different calendars were used. A discussion of some of these calendars would be illuminating.

GEOGRAPHY

1) Distance measured in city blocks is not the same as distance in the usual Euclidean sense. The distance formula becomes $P_1P_2 = |x_1 - x_2| + |y_1 - y_2|$. PD.

## III. Applications Involving Organization and Presentation of Data

An important use of mathematics is the display of facts of relationships in easily understood form. This may involve displays such as tables, where the data are displayed for ease in reading. It may involve charts or graphs, where there is a stronger emphasis on the visual aspects of the relationships. Also, the visual display may be a map, where a region is presented.

### A. Tables

This is a compilation of tables which appear in the texts examined, or which are suggested in the texts.

#### Astronomy

1) A table of the planets, showing the presence or absence of oxygen, water, and living things, the day and night temperatures, and the travel time from the earth. ScC(3-TE)--204.

2) A table showing diameters of planets and their approximate distances from the sun. ScC(3-TE)--417.

3) A table of information about planets. ScA(2-TE)--126.

Botany

1) A table showing whether apple, onion, carrot, parsnip, squash, and macaroni contain starch, as determined by experiment. ScJ(5-PB)--145.

2) Making tables to record seed growth. ScG(Two)--253-258.

3) Tables in which the rates of growth of different parts of a plant are shown. ScG(Four)--595-599.

4) A table of the number of seeds in a fruit and of the total number on a plant. ScG(Four)--601-606.

5) A chart listing the growing conditions when 11 seeds are put in cups and each subjected to different growing conditions. ScA(4-PB)--137.

6) A chart showing two systems for classifying plants. ScK(5-TE)--112.

Chemistry

1) A table of the most common elements. ScD(6-PB)--187.

2) A table of common metals, indicating which of them rust. ScJ(Two--PB)--75.

3) A table of atomic numbers of some elements. ScF--34.

4) A recipe for a blueprint solution. ScF--47.

5) A table indicating whether cooking oil, butter, bacon, sugar, apple, and cheese contained fats or oils. This is determined by experiment. ScJ(5-PB)--147.

6) A suggested activity is to make a table showing the results of a litmus test on washing soda ($Na_2CO_3$), limewater ($Ca(OH)_2$), and lemon juice. ScA(5-PB)--67.

7) A table giving the common elements in the land, the water, and the air. ScA(5-PB)--77.

8) A table showing the amounts of various gases in 100 quarts of inhaled air and 100 quarts of exhaled air. ScA(6-PB)--79.

9) A table of the common alloys, listing the metals contained in the alloy and the uses made of the alloy. ScA(6-PB)--79.

10) A table of selected elements, giving the number of protons, electrons, and neutrons. ScA(6-PB)--269.

11) A table giving the elements in alphabetical order, showing the approximate atomic weight and the number of protons (the atomic number). ScA(6-PB)--291.

12) A table of selected elements, giving the number of protons, the number of electrons, the number of neutrons, and the atomic weight. ScK(5-PB)--269.

Geology

1) Tables of the relative percentages of various types of fossils, and of the percentage of various types of meteorites. ScG(Six)--875-881.

2) A chart of the geological time tables. ScK(5-TE)--137.

Meteorology

1) A table of wind speeds, giving the effects of winds of different speeds, and the designation, such as "breeze", "gale", "hurricane". ScD(6-PB)--82; ScC(4-TE)--415; ScF--208.

2) A table which may be entered with wet-bulb and dry-bulb thermometer readings, to determine the relative humidity. ScD(6-PB)--85; ScC(4-TE)--418; ScF--111.

3) A table for predicting the weather, based on wind direction and air pressure. ScD(6-PB)--87.

4) It is suggested that a record of wind directions be kept. ScJ(Two-TE)--76.

5) A table of inside and outside temperatures. ScJ(Two-PB)--58-9.

6) A daily weather record could be kept in tabular form. ScF--206.

7) A table of the air temperature and the condensation temperature. ScJ(5-PB)--311.

8) A daily temperature record could be put in tabular form. ScA(1-TE)--37.

Physical Geography

1) A table giving the times of high tides. ScC(4-TE)--296.

2) A table of times at different places in the world. ScK(4-TE)--43.

3) A table of the latitudes of major U.S. cities. ScK(4-TE)--44.

4) A table of sundial settings at different latitudes. ScK(4-TE)--47.

Physics

1) A table summarizing data from an experiment. The table includes objects used, weights of the objects, the force needed to lift the objects, and ½ the weight of the objects. ScK(3-TE)--79.

2) A table listing substances and indicating whether they are conductors of electricity. ScJ(Two--PB)--119.

3) The number of seconds candles burn in containers of various sizes can be recorded in tabular form. ScJ(Three-TE)--49; ScJ(Three-PB)--69-71.

4) A table may be made of the distance windup toys move after a certain number of turns of the key. ScJ(Three-PB)--115.

5) A table giving the number of waves in an inch for light of each spectral color. ScA(5-PB)--283.

6) A table of the melting points of selected metals. ScK(4-TE)--155.

7) A table showing the number of calories in a typical serving of some common foods. ScK(5-PB)--257.

8) A table of densities of various substances. ScG(Five)--711-716.

Physiology

1) A table listing a typical diet, with the estimated number of calories for each type of food. ScD(6-PB)--129.

2) A suggested activity is to make a table of the pulse rate for an individual when (a) sitting (b) standing (c) lying down, and after (d) walking, (e) running, (f) hopping. ScJ(Two-PB)--133.

3) A table of hereditary characteristics of relatives. ScF--107.

4) A table showing heights and weights of the students in the class. ScA(1-TE)--122.

5) Each pupil in the class could check his breathing rate for one minute, and a table could be made using the results. ScA(5-PB)--194.

6) A table giving a sample daily menu. ScK(5-TE)--179.

7) A table giving vitamins, what they are needed for, and the foods in which they are found. ScK(5-PB)--249.

8) A table of data for a class, giving the sex of the child, the number of children in the family, the height in inches, the weight in pounds, and the birth month. ScH(VM)--2.

Zoology

1) A table of gestation periods for various creatures is suggested as an activity. ScD(6-PB)--175.

2) A table of animal diets. ScF--25.

3) A table of information on pet animal breeding. ScF--26.

4) A recipe for a bacterial culture. ScF--36.

5) Instructions for making a bird house. ScF--41.

6) A table of the food eaten by various plant-eating animals. ScJ(5-PB)--288.

7) A table of meat-eating animals, showing the animal, his prey, and the food of the prey. ScJ(5-PB)--290.

8) A table of some commonly-used antibiotics. ScA(6-PB)--121.

9) A table of some disease germs we can control, giving the method of control, the scientist who discovered this method, and the date of control. ScA(6-PB)--129.

10) A section on classification and another on living things in an aquarium have many tables. ScG(Three)--317-336.

11) A table recording the results of time-trials as guinea pigs learn to run a maze. ScG(Five)--661-667.

12) Records of the growth of a chick embryo over time can be recorded in tabular form. ScG(Six)--959-965.

13) A table showing the responses of hydras to various stimuli. ScG(4-TE)--61.

Miscellaneous

1) A table of flight times between cities. ScK(4-TE)--61.

2) A table of clothing worn, what the clothing is made of, and the source of the material (plant-made, mammal-made, reptile-made, insect-made, man-made). ScC(3-TE)--134.

3) A table of the International Morse Code. ScC(3-TE)--134.

4) A table put on paper which has been folded to make a tetrahedron, forming an "ecology triangle", which contrasts the desert, a pond community, and the ocean, listing plants, soil or water environment, plant eaters, and meat eaters . ScC(3-TE)--365.

5) A table of the characteristics of man-made materials, including resistance to deterioration by sunlight, resistance to heat, abrasion resistance, wrinkle resistance, resistance to mildew, durability, dimensional stability, care and cleaning. ScC(3-TE)--376.

6) A table which outlines the approach of the text series by showing examples of 6 conceptual schemes and various concept levels within those schemes. ScA(1-TE)--T8-T9.

SOCIAL STUDIES

1) Children can make a log of special events and organize it in tabular form. SSH(AH-TE)--21,22,36; SSH(ITN-TE)--75.

2) A table recording the weather over a period of time would be a good student activity. SSH(ICTQ-TE)--74.

3) A table giving the times of the high and low tides. SSH(IAOS-TE)--125.

4) Vital statistics about each of the states, many of these statistics presented in tabular form. SSH(IAOS-TE)--225-275.

5) Tables may be made up including such information as the land areas of states, countries, or continents, population, population per square mile, amount of rainfall.

ECONOMICS

1) A table of foreign exchange rates could be made. EA(One)--42-3.

GEOGRAPHY

1) Tables can be made for rainfall, elevation, wind velocity, temperature, and other similar items.

READING

1) If you are practicing for greater reading speed or greater reading comprehension, the records may conveniently be kept in tabular form.

B. Graphs and Pictoral Charts

Graphs and charts are used extensively in the elementary school, to give concepts a visual dimension. It would be tedious and highly repetitive to include every graph which was used in the books examined. We have chosen to list those which we felt were especially interesting or especially important uses of graphs.

## SCIENCE

### Astronomy

1) A suggested class project is constructing a line graph indicating the times of sunrise and sunset. ScC(4-TE)--93.

2) A chart showing the relative sizes of the planets. ScC(4-TE)--510.

3) A chart of the constellations. ScC(3-TE)--207; ScA(2-TE)--139; ScK(4-TE)--48; ScK(5-TE)--70.

4) A series of photographs of an eclipse of the moon. ScJ(Five-PB)--165.

5) A chart showing the orbits of the planets and the orbit of a comet. ScA(4-TE)--T-144.

6) Making a model of the orbit of a comet. ScA(4-TE)--263.

7) A graph of the path of an Apollo spacecraft around the moon. ScA(6-PB)--222.

8) A chart showing the phases of the moon. ScC(3-TE)--415.

### Botany

1) As a plant grows, cut off a strip of paper as tall as the plant each day. Pasting the strips on a large sheet of paper gives a bar graph of the growth of the plant. ScJ(One-PB)--100-1.

2) A chart of the growth of two desert gardens, one watered every day and one watered once a week, would be interesting. ScC(3-TE)--32.

3) A chart could be made of the growth of radishes, by pulling up one plant a day for 20 days. ScC(3-TE)--113.

4) Histograms of the number of peas or green beans in a pod. ScH(VM)--14-16, 18-22.

5) Charting the shape and size of mold colonies. ScG(Two)--189-193.

6) A graph of the movement of liquid in the stem of a flower. A line graph would be appropriate here. ScD(3-TE)--56.

7) A graph may be made of the growth of roots, stems, and leaves of bean seeds put in a jar with blotting paper. (The blotting paper has been moistened). ScC(2-TE)--199.

Chemistry

1) The composition of the air (the relative proportions of various gases) could be graphed. A bar graph, rectangular distribution graph, or circle graph would be appropriate. ScE--19; ScD(6-PB)--31; ScC(4-TE)--74.

2) Shading a 10-by-10 region to represent the proportion of gases in the atmosphere. ScA(4-TE)--60.

Geology

1) A chart, partly pictorial, showing geologic eras, the years from the present that these eras occurred, and the forms of life in existence at that time. ScK(5-PB)--194.

2) A geological timeline. ScK(5-TE)--140-1.

Meteorology

1) A bar graph showing the rainfall in different parts of the world. ScC(4-TE)--157.

2) A small thermometer may be drawn in the corner of each day on a weather record, to indicate the temperature on that day. ScI(1-TE)--23.

3) A chart which depicts the types of clouds which form at various altitudes. ScF--63; ScA(6-PB)--417.

4) Line graphs of daily temperatures, showing the daily high and the daily low. ScK(5-TE)--25.

Physical Geography

1) A pictorial representation of spring tides and neap tides. ScC(4-TE)--292.

2) Drawing one's shadow at various times of day makes an interesting visual record. ScJ(Two-PB)--45.

3) A chart of the water cycle. ScC(3-TE)--264.

Physics

1) The force field around a magnet may be shown by using small compasses, iron filings, or sketching. ScD(4-TE)--103; ScD(6-PB)--266; ScJ(Three-PB)--163; ScC(Six)--883-891.

2) Oscilloscope pictures of sound waves are an interesting graphical device.

3) Charts of the electromagnetic spectrum, emphasizing particular portions of the spectrum, such as the visible spectrum, are useful. ScD(6-PB)--216, 218, 220, 222, 224.

4) A suggested project is the construction of a chart of the symbols used in electrical plans and diagrams. ScK(4-TE)--160.

5) A pictorial chart of the Fahrenheit and Celsius (Centigrade) temperature scales. ScK(4-PB)--258.

6) Graphing the motion of a bouncing ball. ScG(Three)--449-454.

7) Some examples of the bright-line spectra of elements. ScA(5-PB)--290.

Physiology

1) When the weight of a child is plotted on a line graph over a period of time, the steepness of the graph at any point is related to the rapidity of growth at that point. ScC(1-TE)--238-9.

2) A view of the chest cavity and the organs in the chest. ScJ(Five-PB)--155.

3) Histograms (X-frequency diagrams) showing variation in family size, and variation in weight. ScH(VM)--3-4.

4) Work in relating graphs to one's field of vision. ScG(Five)--669-679.

Zoology

1) Piles of food show the relative portions of the diet of the sparrow hawk. This is an effective variation of the pictograph. ScD(3-TE)--119.

2) A bar graph of the gestation periods for various mammals, including man. ScD(5-PB)--274.

3) A circle graph showing the proportions of different kinds of insects in the world. Pictures of the types of insects are included on the appropriate sectors of the circle graph. ScC(4-TE)--365.

4) A graph showing the speeds of the fastest animals on land, in the air, and in the sea, would be interesting. ScK(2-TE)--51.

5) A chart showing the changes in appearance of a chick embryo. ScF--85.

6) A pictorial food chain, from largest to smallest; Pickerel-Perch-Diving Beetle-Young Dragonfly-Water Flea (Daphnia)-Tiny plants. ScJ(Five-PB)--24-5.

7) A pictorial chart of the life cycle of a mallard duck. ScA(4-TE)--201.

8) A pictorial chart of the evolution of the horse. ScA(5-PB)--313.

9) A pictorial chart showing the life forms and the quality of light at different ocean depths. ScK(5-PB)--230.

10) Making a graph of the size of brine shrimp against the number of days after hatching. ScG(Six)--855-860.

11) A pictorial table of bacterial treatments. ScG(Three)--459-463.

Miscellaneous

1) A bar graph comparing the height of a building, the height to which a bird can fly, and the height of a mountain. ScC(4-TE)--277.

2) A bar graph could be made of the speeds of different types of aircraft, and the heights reached by these aircraft. ScC(4-TE)--277.

3) The outlines for a glider are indicated on squared paper. ScC(4-Te)--473.

4) A chart showing the musical scale. ScF--181.

5) A chart showing the different kinds of clothing we wear. ScC(3-TE)--131.

6) A pictorial chart showing what could be made from 5 gallons of milk: 21 large cans of evaporated milk; 4 lb. of American cheese; about 1¾ lb. of butter; 5 lb. of dry whole milk. ScA(2-TE)--101.

7) A chart of the seven basic food types. ScA(2-TE)--124.

8) A chart of semaphore flag signals. ScK(5-TE)--214.

9) A discussion of extrapolation, interpolation, the use of coordinates, and other matters relating to graphs. ScG(Commentary for Teachers)--110-112.

10) Work using interpolation and extrapolation for purposes of prediction. ScG(Three)--337-340.

11) Plotting of forgetting and relearning curves. ScG(Six)--917-924.

12) Model life cycles (vector graphs). ScG(Six)--966-984.

SOCIAL STUDIES

1) Making a time line. SSH(ICTC-TE)--74; SSH(IAOS-PB)--163.

2) A sociogram of a class. SSH(IAOS-TE)--18.

3) A pictograph showing the value of surplus farm products owned by the government, 1950-1960. SSH(ITA-TE)--126.

4) A bar graph showing the major uses of steel in the United States. SSH(ITA-PB)--131.

5) A bar graph of the amount of electricity used in U.S. homes, 1934-1959. SSH(ITA-PB)--146.

6) A chart showing the effect of 100 new industrial jobs on a community. SSH(ITA-PB)--151.

7) A pictograph of the growth in U.S. population, 1790-1960. SSH(ITA-PB)--176.

8) Bar graphs for boys and girls showing the average U.S. life span, 1900-1960. SSH(ITA-PB)--177.

9) A pictograph of the population shift to urban areas, 1790-1960. SSH(ITA-PB)--185.

10) A circle graph, showing the source of the budget dollar in 1960. SSH(ITA-PB)--204.

11) Pictographs of the number of paid civilian employees, 1821-1960, and of the money spent by the U.S. government, 1821-1960. SSH(ITA-PB)--205.

12) A pictograph showing the percent of Canadian workers in each of their major occupations. SSH(ITA-PB)--279.

13) A chart showing the effect of altitude on crops in tropical lands. SSF(TE)--12.

14) An example of a line graph with the area shaded in below the graph. SSF(TE)--103.

15) A pictograph showing what it costs to move one ton one mile by different means of transportation. SSD(TE)--371.

16) The food eaten by an average person in one week in different parts of the world is presented in pictograph and numerical form. SSG(TE)--2-5.

17) A graph of the travel time, coast to coast, 1850-1960. SSG(TE)--93.

18) Pie graphs of where we obtain certain metals. SSG(TE)--276.

19) A cross section graph of the depths of the Great Lakes. SSB(4-TE)--92.

ECONOMICS

1) A pictorial display showing how many hours it takes workers in various parts of the world to produce certain goods. EA(2)--13.

2) Varying sizes of baskets filled with appropriate items are used to show how goods and services have increased every 10 years. EA(2)--14.

3) A visual exhibit "Money Is Worth Just As Much As It Can Buy", EA(2)--16.

4) Charts and graphs depicting the population growth of Little Rock, 1900-1964, the effect of 1300 employees with a $7.5 million payroll on the city, and "What 150 jobs mean to Little Rock". EC--14-20.

5) The percentage of profit may be graphed for several companies. This information may be obtained by getting the annual reports of these companies. PE.

6) A "Standard and Poor" report on a company may be obtained from a broker. (Some brokers will supply these free, others will charge for them). The percentage of profit turned back into the business can be graphed over a period of time. PE.

GEOGRAPHY

1) Geographic data is often adjusted for regional variation in the same way that economic data is adjusted for seasonal variation. PD.

READING

1) The number of outside books read by different students in a period of time could be graphed.

2) The scores on reading tests could be graphed.

CURRENT EVENTS

1) Graphs could be made of the distance various types of missiles can travel, and the time it takes these missiles to traverse these distances.

C. Maps and Mapmaking

Maps are used extensively in the elementary curriculum, particularly

in history and geography. Because maps are so frequently used, we will only mention maps that are of particular interest or are representative of particular types of maps. Some attention is also given in textbooks to the mapmaking process--the distortion in different projections, for example--and some of these discussions are cited here.

## SCIENCE

### Meteorology

1) A weather map. ScD(6-PB)--48,88; ScJ(Five--PB)--311; ScA(5-PB)--416.

2) Rainfall maps. ScC(4-TE)--158, 164; ScK(4-PB)--37.

### Physical Geography

1) A pupil activity is the tracing of the equator on maps and globes. ScC(4-TE)--150.

2) Making world maps, and a discussion of the distortion of the polar regions occurring on some map projections. ScC(3-TE)--69.

3) A map of the Columbia River. ScC(3-TE)--90.

4) A map of the United States, showing meridians and lines of latitude. ScK(4-TE)--50.

5) Working with maps of the polar regions, indicating the position of glaciers, tundra, etc. ScK(4-TE)--66.

6) Outlining deserts on a world map. ScK(4-TE)--103.

7) Maps showing funnel-shaped bays (which result in exceptionally high tides). ScK(4-TE)--135.

8) A map of the standard time zones. ScK(4-TE)--57-8.

9) Maps showing the ocean currents. ScK(5-TE)--29; ScK(5-PB)--48.

10) Contour maps. ScG(Six)--935-941.

### Zoology

1) A map showing the Central Flyway for migratory game birds. ScA(4-TE)--200.

Miscellaneous

1) A suggested pupil activity is the making of maps of the room, the neighborhood, and the routes to school. SoC(2-TE)--53.

2) Map showing the route of the Nautilus under the Arctic ice cap. SoC(4-TE)--430.

SOCIAL STUDIES

1) Picture maps. SSH(AS-TE)--90-1; SSH(AS-PB)--92-3; SSH(ITN-PB)--39,103,143,180.

2) A discussion of making and reading maps, including 3-dimensional models, pictorial and semi-pictorial maps, aerial maps, picture maps, symbolized maps, street and road maps, and globes. SSH(ITN-TE)--56-63.

3) A map of metropolitan areas in the United States. SSH(ICTC-TE)--103.

4) A flannel map of schools in the community would be useful. SSH(ICTC-TE)--157.

5) Locating educational facilities, recreational facilities, or business centers on flannel maps or pupil copies of maps. SSH(ICTC--TE)--161, 175.

6) Discussion of a map key. SSH(ICTC-PB)--64.

7) A map showing regions of the United States. SSH(IAOS-TE)--48.

8) A water resources map. SSH(IAOS--TE)--183; SSH(IAOS-PB)--204.

9) A population map of the Northeast. SSH(IAOS-PB)--94.

10) A product map of the North Central states, where the products are represented pictorially. SSH(IAOS-PB)--128.

11) A waterways map of the South. SSH(IAOS-PB)--162.

12) A map showing the Oregon and Santa Fe Trails. SSH(IAOS-PB)--192.

13) A discussion of the earth and globes. SSH(IAOS-PB)--209-213.

14) A discussion of pictorial relief maps, physical-political maps, history maps, and special-purpose maps. SSH(ITA-TE)--65-71.

15) Toscanelli's map (an early map). SSH(ITA-TE)--105.

16) A map showing the route of Indian migration from Asia. SSH(ITA-PB)--9.

17) A map showing the distribution of Indian tribes in North and South America. SSH(ITA-PB)--38.

18) A map of Columbus' journeys. SSH(ITA-PB)--46.

19) A map of Magellan's circumnavigation of the globe. SSH(ITA-PB)--49.

20) A map showing areas in the New World claimed by European powers in 1700. SSH(ITA-PB)--59.

21) A map of the United States showing the regions ceded to the United States and the dates of cession. SSH(ITA-PB)--84.

22) A map showing dates of admission of states to the Union. SSH(ITA-PB)--88.

23) Population maps of the United States in 1800, 1850, 1900, and 1950. SSH(ITA-PB)--89.

24) Relief maps of the United States. SSH(ITA-PB)--118-121.

25) A map of the growing season for the United States and Canada. SSH(ITA-PB)--122.

26) A land use map of the United States and Canada. SSH(ITA-PB)--124.

27) A map showing the kinds of farming in the United States and Canada. SSH(ITA-PB)--125.

28) A map of the United States, showing the deposits of coal, iron ore, and steel. SSH(ITA-PB)--130.

30) A map showing the fisheries in the United States, Canada, and northern South America. SSH(ITA-PB)--136-7.

31) A map of the major manufacturing areas in the United States, showing the types of manufactures. SSH(ITA-PB)--155.

32) Transportation maps of the United States, showing railroad lines, interstate highways, and navigable waterways. SSH(ITA-PB)--158, 159, 162.

33) A map showing strip cities of the United States. SSH(ITA-PB) --188.

34) A map showing the national parks in the United States. SSH(ITA-PB)--219.

35) A map showing the location of different minerals in Canada. SSH(ITA-PB)--251

36) A discussion of the problems involved in making a flat map of the earth. SSH(BTA-PB)--14-17.

37) A drainage map. SSD(PB)--13.

38) Average temperatures for January and July are shown by thermometers on a map. SSE(TE)--C-80, 81.

39) A Mercator projection. SSG(TE)--82.

40) A North polar equal-distance map. SSG(TE)--83.

41) Contour maps. SSG(TE)--226.

IV. Applications Involving Algebra

Algebraic ideas are frequently used in the elementary school, particularly in the upper elementary grades. The idea of relations and functions is a major theme. Some relationships are most conveniently expressed by means of formulas. In other cases, the connection between the variables is as conveniently expressed in words. We have included examples of algebraic relationships drawn from the sources examined.

SCIENCE

Meteorology

1) Air Pressure varies with altitude, decreasing as altitude increases. ScD(4-TE)--42; ScK(4-TE)--26.

Physics

1) The boiling point of water decreases as altitude increases. ScD(4-TE)--148.

2) The gravitational force between two objects is inversely proportional to the square of the distance between the two objects. ScD(5-PB)--160.

3) The formula for work, Work = Force x Distance, is given. ScD(5-PB)--182-3; ScK(4-TE)--170; ScK(5-TE)--21.

4) The law of the lever, $W_1D_1 = W_2D_2$, is discussed. ScD(5-PB) --185; ScC(3-TE)--156-161.

5) The effect of gears of different sizes in changing speeds is discussed. ScD(5-PB)--186.

6) Two formulas for efficiency are presented:

(a) $\text{Efficiency} = \frac{\text{Weight of object x Height raised}}{\text{Work put in}}$

(b) When using a pulley to lift an object and measuring the work with the help of a scale of some type,

$$\text{Efficiency} = \frac{\text{Weight of object x Height raised}}{\text{Reading on scale x Dixtance scale pulled}}$$

ScD(5-PB)--196.

7) The formula for electrical resistance is stated in the form

$$\text{Resistance (in ohms)} = \frac{\text{voltage}}{\text{amperes}}$$ . ScD(5-PB)--281.

8) Water pressure increases as the depth below the surface of the water increases. ScD(5-PB)--302-3.

9) The force of gravity between two objects diminishes as the distance between the objects increases. ScC(2-TE)--135.

10) Newton's third law, "For every action there is an equal and opposite reaction", is discussed. ScC(4-TE)--224-5; ScA(4-TE)--104.

11) Work is described roughly as the movement of an object from one place to another. ScC(1-TE)--55.

12) The formula W = F x D for work is given. It is pointed out that this means a change in force requires a change in distance, if the amount of work is to remain constant. ScK(2-TE)--125; ScK(5-TE)--44-5.

13) The principle of action and reaction is shown by discussing a boat in water. The boat pushes on the water, and the water pushes back on the boat. ScJ(Five-TE)--35.

14) "Going faster means more work is done per unit time". ScA(1-PB)--13.

15) The rate at which energy is used determines how fast the work can be done. ScA(1-PB)--14.

16) "The more work done, the more energy needed." ScA(1-PB)--15.

17) More work can be done in less time when machines are used. Machines do not reduce the total amount of work. ScA(1-PB) --16.

18) Work is characterized as a force acting through a distance. ScA(1-PB)--20; ScG(Six)--895-898.

19) Mechanical advantage is defined as the ratio of the load to the applied force. ScK(4-TE)--171.

20) There is a relationship between the size of the wheel on a windlass and the effort needed to lift a load by the windlass. ScK(4-TE)--175.

21) The work required to move an object from the bottom to the top of an inclined plane may be expressed by the formula W = length of plane x force.

22) The Bernoulli principle is expressed as $P + \frac{KE}{V} = k$.

23) The relation $E = mc^2$, which is the famous equation developed by Einstein showing the relation of mass and energy, is discussed. ScK(5-TE)--23.

24) The formula for power is $P = \frac{W}{t}$. ScK(5-TE)--44-5.

25) A suggested enrichment topic is an investigation between the intensity of light and the distance from the light source. ScK(5-TE)--77.

26) The number of swings that a pendulum takes in a minute is related to the length of the pendulum. ScG(Five)--681-688.

27) The relation between the number of identical objects suspended on the end of a spring and the elongation of the length of the spring or rubber band is a topic for investigation. ScG(Five)--681-688.

28) The time for an object to fall a given distance depends on the amount of resistance encountered. ScG(Five)--717-721.

29) All objects starting from rest take the same time to fall equal distances provided the force of resistance encountered is small compared to the weight. ScG(Five)--717-721.

30) To produce greater acceleration, a larger force is needed. ScG(Five)--731-736.

31) A larger force is needed to give equivalent acceleration to a larger mass. ScG(Five)--731-736.

32) Boyle's Law, that in a gas the product of the pressure of the gas and its volume is constant, is investigated through experiments. ScG(Five)--769-774.

33) A study of the length of a yardstick, how far the yardstick seems to extend into a mirror, and how far back "in the mirror" the image appears. ScA(2-TE)--71.

Physiology

1) One's pulse rate varies with age, decreasing as one gets older. ScD(4-TE)--243.

2) The growth of one's hand size and foot size with age is discussed. ScJ(One-TE)--52-3.

Zoology

1) A suggested experiment is an investigation of the relationship between the temperature of water in an aquarium and the rate of respiration of a fish in the aquarium. ScA(4-TE)--T-109.

SOCIAL STUDIES

1) The higher one goes in the air, the larger is the area that can be observed. SSH(ICTC-TE)--171.

2) The relationship between latitude and temperature is discussed. SSD(TE)--19.

ECONOMICS

1) The principle of opportunity costs: The cost of an item is compared to the enjoyment which may be derived from the money if it is used in another way. EF--8-9.

2) There is a relationship between prices and the level of living. EF--10.

3) The price level and the value of the dollar move in opposite directions. EF--11-12.

4) Prices cannot increase faster than (money) income. This is a general effect, not an individual effect, however, so the individual may be worse off. EF--12.

5) Profit will be increased or losses will be reduced so long as the price exceeds the variable cost for each additional item sold. EF--15.

6) The dollar value of all that is produced is equal to the dollar value of the income received. EF--20.

7) The demand for necessities tends to be inelastic, but the demand for luxuries tends to be elastic. EA(One)--16.

8) Money has three functions: (1) A medium of exchange; (2) A measure of value; (3) A store of value. EA(One)--32.

9) Examples of the principle of opportunity costs are; (1) Buying balloons, drinks, or candy at a circus or saving the money for the bus ride home; (2) the use of time; (3) Buying art supplies with a limited income. EA(2)--7.

10) Pricing formulas are used by the Big Three automobile manufacturers in pricing their cars. PE.

11) Simple and compound interest and the related formulas may be studied. PE.

12) Budgeting "formulas" are sometimes presented, in which the amount the average family should spend for essentials of various types is shown. PE.

13) The effect of inflation and deflation on the budget may be investigated. PE.

14) The effect of a raise on the level of prices may be investigated. PE.

15) The question may be studied of whether it is best to get a cost-of-living raise each year. PE.

16) The effect of buying cheaper merchandise on prices may be investigated. PE.

17) The return per share on different types of stock may be investigated. PE.

GEOGRAPHY

1) A good estimate of the number of people traveling between two cities with populations $P_1$ and $P_2$ respectively is $\frac{P_1 P_2}{D}$, where D is the distance between the two cities. PD.

2) The density of population in a city is a declining function of the distance from the center of the city. PD.

3) An investigation may be carried out by the students where the effects of elevation on the type of food which may be grown is studied.

4) The effect of the depth of the water at which fish live and their shape and form could be studied.

MUSIC

1) There is a relation between the length of a taut string and the tone it produces when struck or plucked.

V. Applications Involving Ratio, Proportion, or Comparison

The applications listed here are those which emphasize comparison between quantities. An important method of comparison is ratio.

# SCIENCE

## Astronomy

1) A comparison is made between the weight of an object on the earth and the weight of the same object on the moon. ScD(1-TE)--54; ScA(5-PB)--94.

2) The lengths of orbits of various planets are compared. ScD(3-PB)--13.

3) The size of the earth is compared with the size of the moon. ScD(3-PB)--14; ScC(3-TE)--209.

4) The gravitational pull of the moon is compared to that of the earth. ScC(2-TE)--136.

5) The sizes of the planets are compared. ScC(4-TE)--298.

## Botany

1) A record of the comparative growth of different types of plants. ScD(3-PB)--48.

## Chemistry

1) The relative amount of iron in iron ore is discussed. ScC(2-TE)--295.

## Meteorology

1) The weight of warm air is compared to the weight of cold air. ScA(4-TE)--T-44.

## Physics

1) The relative turning rates of two gears of different size is observed. ScD(3-PB)--91.

2) The relative speeds of sound and light are discussed. ScD(3-PB)--172-3; ScK(5-TE)--200.

3) A comparison is made between the heat energy in a barrel of water at 150° F. and a teacup of water at 150° F. ScD(6-PB)--251.

4) The comparative strengths of two magnets are established by determining how many tacks they can pick up. ScC(2-TE)--171.

5) Rolling friction is compared to sliding friction. ScC(4-TE)--214; ScA(6-PB)--181.

6) The force of steam power is compared to the force of water power. ScC(4-TE)--251.

7) A comparison between the forces needed to move up two inclines of different slope. ScF--171.

8) A comparison of the reflection and absorption of light vs. dark materials. ScC(3-TE)--153.

9) Gear ratios are investigated in an eggbeater and a hand drill. ScC(3-TE)--163.

10) A comparison is made between the distance traversed in 2 steps on foot and the distance traversed in 2 steps on a bicycle. ScC(3-TE)--165.

11) The ratio between the weight of an object on the earth and the Earth's gravitational force on that object is 1:1. ScA(5-PB)--93.

12) The length of the tube in a mercury barometer (30") is compared to the length of the tube in a water barometer (34'). ScK(4-TE)--24.

13) The density of substances is compared to the density of water. ScG(Five)--711-716.

14) Masses are compared using acceleration boards. ScG(Five) --737-743.

15) The distance a cylinder rolls at the bottom of an incline is compared to the height of the incline. ScG(Six)--899-904.

Physiology

1) The ratio of the red corpuscles to the white corpuscles in the blood is discussed. ScF--46.

2) The heights of first graders (for example) can be compared to the heights of babies, the heights of sixth graders, and the heights of teachers. ScA(1-TE)--123.

Zoology

1) The length of a grasshopper is compared to the distance he can jump. ScC(4-TE)--355.

Miscellaneous

1) In making concrete, a 1-2-3 mixture of cement, sand, and gravel is used. ScC(2-TE)--71.

2) The length of a soda bottle is compared to the length of a child, and the circumference of the soda bottle to the circumference of the child. This investigation involves making estimates and revising these estimates on the basis of the experimental results. ScH(VM)--39.

3) A section on similarities and differences involves many comparisons. ScG(One)--27-29.

4) A section on variation in objects of the same kind includes comparisons in length, area, volume, and shape. ScG(Two)--181-183.

SOCIAL STUDIES

1) Comparisons may be made between populations in different states, countries, regions, cities, etc.

ECONOMICS

1) Comparisons and contrasts are made between life insurance, health insurance, disability insurance, and property insurance. EF--32.

2) The ratio of taxes paid and profits made may be figured for different companies. PE.

3) A comparison may be made for different companies between their sales and their expenditures for labor and costs. PE.

4) The amount expended by a corporation for research and development may be compared with the amount of profits, and with the amount retained in the business for modernization, repairs, etc. PE.

5) The percentage of return a stockholder gets (figured by computing the amount of return they get per share, and dividing this by the par value of the share) may be compared to bank interest. PE.

6) The ratio of supply and demand may be compared to the price of the item. A good example is the study of vegetable prices at different times of the year. PE.

VI. Applications Involving Geometry

Elementary school students live in a world of geometric objects (or physical approximations thereto). Geometry plays a part in all areas of human activity. The applications below are examples of applications which may help to make students more aware of geometry in their world.

## SCIENCE

### Astronomy

1) A suggested activity is making scale models of the planets. ScF--153; ScJ(Five-PB)--181.

2) A mention that the orbit of the moon is slightly elliptical. ScC(3-TE)--192.

3) At the first grade level, the orbit of a space capsule should not be called circular, but the word ellipse should be avoided at this time. ScA(1-TE)--53.

4) The earth's orbit is an ellipse. ScA(5-PB)--116.

5) The orbit of the moon around the sun is discussed. ScA(5-PB) --123.

6) A section concerned with describing the motion of the sun across the sky. ScG(Two)--265-272.

### Botany

1) An experiment: How is a fat shape useful to a desert plant? ScC(3-TE)--30.

### Physical Geography

1) The angles that sunlight strikes the earth in different regions of the earth are discussed. ScC(4-TE)--151.

2) Experiments related to the angle of sunlight are suggested. ScC(4-TE)--432.

3) The directions North, East, West, South are presented. ScJ(Two-PB)--41.

4) Longitude and latitude are discussed using an orange as a model. ScK(4-PB)--54.

5) A three-dimensional coordinate system is employed in connection with contour maps. ScG(Six)--935-941.

### Physics

1) Some study is made of the effect of the shape of a container on the rate of evaporation. ScJ(Three-TE)--31.

2) Some investigation is made of the effect of a large base on the stability of a box, and of the effect of a low center of weight on the stability of an object. ScJ(Five-PB)--65.

3) Information is given for making a mobile. ScJ(Five-PB)--68.

4) A discussion of the relation of the angle of reflection to the type of surface--whether the surface is regular or diffuse. ScA(4-TE)--T-22.

5) The refraction of light. ScA(4-TE)--T-25-T-27; ScA(4-PB)--38-42.

6) Polarized light vibrates in just one plane. ScA(4-TE)--T-30.

7) Some work with the angle of reflection. ScA(4-PB)--32-3.

8) The effect of different locations of the fulcrum of a lever is investigated. ScA(6-PB)--162.

9) Balancing a seesaw is discussed. ScA(6-PB)--193.

10) A discussion of crystal shapes. ScK(4-TE)--78-9.

11) To see oneself full length, one must look into a mirror that is at least half as tall as one is. ScK(5-TE)--9.

12) An experiment to determine if slanted rays give off less heat or more heat than direct rays. ScK(5-TE)--99.

13) A collection of children's suggestions for measuring areas. ScH(VM)--43.

14) Making scale drawings of lakes, and measuring the size of the lakes using beans. ScH(VM)--44.

15) Filling different-shaped containers to the same level can provoke a discussion of volume. ScH(VM)--49-50.

16) The introduction of Mr. O as an origin, or reference location. ScH(RPM)--18-19.

17) The notion of center of gravity is discussed. ScH(RPM)--30.

18) Some work in ordering objects by length, and in checking whether two objects have the same length. ScG(One)--85-88.

19) Some work with going a given distance in a given direction. ScG(One)--117-122.

20) A section on comparison of volumes, where the volume of a solid is distinguished from its height or width, containers are ordered by volume, both by inspection and by pouring, and volumes are compared to a unit volume. ScG(Two)--201-205.

21) A section dealing with the description of an expanding balloon. ScG(Two)--227-231.

22) A section on measuring volume. ScG(Three)--407-411.

23) An experiment dealing with the three states of matter involves the idea of shape. ScG(Four)--499-503.

24) A section on the color wheel deals with geometric shapes of different colors. ScG(Four)--579-586.

25) A section on relative position and motion. ScG(Four)--613-616.

26) A section on the measurement of angles where reflections are involved includes methods of naming rays, lines, and angles, the measuring of angles with protractors, and Snell's Law (the angle of incidence equals the angle of reflection). ScG(Five)--701-709.

27) A section on force and motion uses vector diagrams. ScG(Five)--723-730.

28) The effect of sunlight at the North Pole and at the center of the United States may be simulated by propping a thermometer up with books at different angles. This should be done in a place where the sun shines on the thermometer. The temperature should be recorded at regular intervals, such as every fifteen minutes. ScC(4-TE)--135.

Physiology

1) A pair of experimentally-oriented sections deal with interpreting the field of vision using graphs. ScG(Five)--669-679.

2) The two-thumbtack method of drawing an ellipse is discussed. ScJ(Five-PB)--175; ScA(5-PB)--117.

3) Ellipses are discussed. ScA(4-PB)--264-5.

4) A discussion and investigation of the variation in pattern of floor tiles, and with the distribution of this pattern on the tiles. ScH(VM)--26-30.

5) The distance around concentric circles can be measured using a unit such as the length of one child's foot. ScH(VM)--37-9.

6) The notion of geometrical center is discussed. ScH(RPM)--29.

7) Assymetrical systems are compared with symmetrical ones. An excellent statement about symmetry is "For a completely symmetrical system there are two or more equivalent observers, differently-placed Mr. O's that can observe the system in the same way." ScH(RPM)--41.

8) Various symmetrical systems are shown and discussed, such as the letter N, an equilateral triangle, a . ScH(RPM)--44-5.

9) Symmetrical designs are constructed from parquetry blocks. ScH(RPM)--45-7.

10) A simple development of work with coordinates. ScH(RPM)--47-9.

11) First-graders should be able, by the end of the year to:
(a) Distinguish angular direction in space;
(b) Identify lines, planes, and angles in complex objects;
(c) Identify symmetrical forms;
(d) Match symmetrical halves in two and three dimensions;
(e) Measure, estimate, and compare lengths and widths.
ScG(Commentary)--26.

12) By the end of third grade, a child should be able to locate objects and places on grids and graphs. ScG(Commentary)--27-8.

13) Vector quantities are contrasted with nonvector quantities. ScG(Commentary)--108-9.

14) A section on recognizing common two-dimensional shapes as components of complex objects includes the circle, rectangle, square, triangle, and ellipse. The ellipse is presented as the shape of a circle seen at an angle. The two-tack method of constructing an ellipse is included. ScG(One)--5-11.

15) A section on shapes and their components includes the construction of triangles, circles, squares, rectangles, and ellipses. Recognition of the sphere, cube, cylinder, pyramid, and cone are sought, as is the identification of two-dimensional shapes bounded by the edges of regular three-dimensional shapes. The shapes learned are applied to crystals, bacteria, body cells, and plants. Emphasis is laid on the constancy of the shape when viewed from different directions. The ellipsoid is related to the ellipse, and the sphere is related to the circle. ScG(One)--13-18.

16) A section on angles groups angles into 3 types: right angles; angles smaller than right angles; angles larger than right angles. ScG(One)--111-115.

17) A section on symmetry, discussing both axes of symmetry and planes of symmetry. ScG(Two)--151-156.

18) A section on the shapes of animals, which deals with bilateral symmetry, the description of body form in terms of geometric shapes, and sketching planar shapes to build up common objects. ScG(Two)--157-161.

19) A section on shadows, which deals with 2-dimensional projections of 3-dimensional objects. ScG(Two)--219-225.

20) A section on straight and curved lines and surfaces, including open and closed curves, paths on surfaces, surfaces which are flat and those which are not flat, and great circles. ScG(Two)--259-265.

21) The number of corners, edges, and faces on a regular solid are studied, to ascertain the Euler relationship. ScG(Two) --285-289.

22) A section on ordering plane figures by area includes animal footprints as well as standard geometric shapes, and includes the use of grids. ScJ(Three)--347-361.

23) A section on locating objects and places by the use of coordinates. ScG(Four)--553-560.

24) A section on two-dimensional representations of spatial figures deals with lantern projections of three-dimensional objects such as Tinkertoy models. ScG(Four)--587-594.

25) A section, Inferring Shapes of Cut Things, teaches about cross-section, longitudinal sections and diagonal sections. The relation of the shape of the object and the angle of cut to the geometric pattern produced by cutting is discussed. ScG(Five)--745-753.

## SOCIAL STUDIES

1) Orientation: left, right; front, back; side; near, far; up, down. SSH(AH-TE)--57-8.

2) The cardinal directions (N, E, W, S). SSH(AH)--57-8; SSH(ITN-TE)--64-6; SSH(IAOS-TE)--42.

3) Longitude and latitude are discussed. SSH(BTA-PB)--12-13.

4) The angle of the sun's rays at different times of year is discussed. SSE(TE)--85-87.

5) Great circle routes are the shortest for airplanes.

## GEOGRAPHY

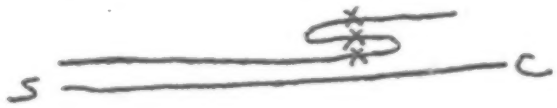
1) If conditions all over the earth were the same, the appropriate geometric model for the distribution of cities would be the close packing model. PD.

2) Cities tend to grow in concentric circles around their centers--this is distorted by the linearities of river transportation. PD.

3) A city road system is highly similar to the vein pattern in a leaf; in both cases the paths tend to be geodesics. Example: Detroit is much like a maple leaf in layout. (Don't push this analogy too far). PD.

4) A geographer speaks of the "one-hour-circle" around a city. The "circle" is made up of all points one hour away from the center of the city. These "circles" are not Euclidean circles. PD.

5) In traveling from Seattle to Chicago, there may be several points that it would take the same time to arrive at (one may be reached by flying to an airport and then driving back, another by plane alone, etc.) PD.




ART

1) Geometric shapes are used extensively in designs.

2) The golden rectangle appears over and over in art.

3) Solid and two-dimensional shapes are used in architecture, both functionally and ornamentally.

4) The structure of bridges is a nice application of geometry (e.g., triangles for strength).

NATURAL HISTORY

1) There are a variety of geometric shapes in nature.

## VII. Applications Involving Probability and Statistics

The mathematics of chance and uncertainty play an important part in the modern world. Many of the ideas from the areas of probability and statistics are quite easily learned by elementary school children. In the future, more emphasis on these topics will probably characterize our mathematics program at all levels. Here we have listed some places where these topics are usefully applied to other areas of the curriculum.

SCIENCE

### Astronomy

1) The number of stars in the sky, or in some portion of the sky, may be estimated by sampling techniques. A small portion of the sky may be selected and the number of stars in that region counted. That number may be multiplied by the ratio of the larger region to the smaller region. ScA(6-PB)--384-5.

Botany

1) A number of pods of peas are shelled, and the number in each pod recorded. The modal number of peas is determined, the idea of range is developed, and the most likely numbers of peas in a pod are established on the basis of the experiment. ScH(VM)--17.

2) The same sort of analysis as in (4) is performed, with the investigation concerning the number of green beans in a green bean pod. ScH(VM)--18-22.

3) The frequency distribution of the number of leaflets on an ash tree leaf is studied. It is learned that an odd number is more prevalent than an even number, and that 7 is the most likely number. ScH(VM)--22-24.

Meteorology

1) Weather forecasts are now expressed in probabilistic terms, such as: "The precipitation probability is 20%".

Physics

1) In an experiment to determine the force needed to move a book, the force is measured by a spring balance. The average of the three trials is taken as the value of the force. ScC(4-TE)--210.

2) Maps of lakes are covered with beans to measure the areas of the lakes. Different-sized beans are used, and the variations are noted. ScH(VM)--44-46.

3) An investigation is made of the cubit length--the distance from the elbow to the tip of the middle finger--and the variation in this distance among the class. The same sort of thing is done with the length of the children's feet. ScH(VM)--55-57.

4) A study of the variation in the length of a rock introduces the idea of reliability of measurement. ScH(VM)--58-59.

5) In an experiment dealing with the interpretation of smoothness in terms of resistance to sliding, trials are averaged. ScG(Three)--395-401.

6) In a section which deals with describing the motion of a bouncing ball, interpolation is involved. ScG(Three)--449-454.

7) In a study of suffocating candles, prediction is used and experimental error is discussed. ScG(Four)--527-531.

8) Means are calculated in a variety of situations, such as: the force required to break a string; the distance an object slides; the height of bounce of a ball; the time it takes a BB to fall in a viscous medium; the volume of a marble; temperatures. ScG(Six)--925-933.

Physiology

1) A study is made of the variation of body weight within a class, and between grades of the school. ScH(VM)--57-8.

Zoology

1) In a study of changes in snail population, prediction by means of extrapolation is used. ScG(Four)--543-548.

Miscellaneous

1) Sampling techniques of various types are employed to count large numbers of objects. ScA(6-PB)--382-3.

2) A suggested extension topic is to flip a coin 100 times and see if the result agrees with our intuition. ScK(4-TE)--13.

3) An experiment is concerned with the variation in the number of raisins in a slice of raisin bread. This is usually a fairly wide distribution. ScH(VM)--24-6.

4) An investigation is made of the variation in pattern of floor tiles, and the distribution of this pattern on the tiles. ScH(VM)--26-30.

5) A section deals with simple probabilistic situations, identifying outcomes as favorable or unfavorable, and recording the results. ScG(Five)--755-762.

6) An investigation of the effect of the amount of study upon learning by memorization (of state capitals) involves considerable statistical work. ScG(Six)--865-874.

7) A section on forgetting and relearning repeats the experiment of (6), and also repeats the statistical work, as well as introducing some additional statistical calculations.

8) A section on the analysis of chance involves: probability trees and chains; "or" and "and" statements and their probabilities; the counting of possible experimental outcomes. ScG(Six)--943-956.

SOCIAL STUDIES

1) The average temperatures for January and for July are shown on a map. SSE(TE)--C-80-81.

2

2) Newspapers and magazines are full of statistical information.

3) The students in the class could carry out surveys.

ECONOMICS

1) Marketing research involves the taking of polls. PE.

GEOGRAPHY

1) The correlation between the area of a city and its population is about .9. PD.

VIII. Applications Involving Proof and Deductive Inference

It is generally agreed that elementary school students are not ready to prove sophisticated theorems in a rigorous way. However, there are many experiences which help to prepare the way for formal proof. Some such experiences are included here.

SCIENCE

Chemistry

1) A section deals with inferring the presence of water vapor in air. ScG(Four)--481-491.

2) A section on inferring the composition of cloth. ScG(Five) --657-659.

Physics

1) A section on inference of patterns through the use of electric circuits. ScG(Five)--651-656.

Miscellaneous

1) A section on charades provides an introduction to inference. ScG(Three)--385-387.

2) A section deals with inferring the characteristics of packaged articles. ScG(Three)--389-393.

3) A section on observations and inferences sets up several inferential situations. ScG(Four)--481-491.

4) A section on inferences in familiar situations. ScG(Four) --571-577.

## IX. Applications Involving Sets

Set theory is usually considered to be a unifying topic. In this sense, sets remain in the background in many places, and as such have been included many times in this collection of applications. For example, geometry is the study of sets of points and relations among certain of these sets. However, sets sometimes stand alone as a separate topic. This is true in the applications presented here.

SCIENCE

1) A section on sets and their members, where, among other things, objects are classified into sets by shape. ScG(One)--19-22.

2) A section on observing color, shape, and texture to identify sets and their members. ScG(One)--23-26.

GEOGRAPHY

1) Political jurisdictions are good examples of set intersections and unions. For example, a school district, a city boundary, a "fire district", etc., usually have overlapping, rather than identical, boundaries. PD.

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PB Mrs. Edmister, reader-critic, U.S.O.E. Elementary Materials Writing Project.

PC Dr. Theral T. Herrick, Executive Director of the Michigan Council on Economic Education.

PD Professor Waldo Tobler, Department of Geography, The University of Michigan.

PE Donald Beard, Assistant to the Director, Institute for Economic Education.